

Detailed Analyses of Precipitation Patterns Associated With Mesoscale Features Accompanying United States East Coast Cyclogenesis

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ABSTRACT—Detailed hourly precipitation patterns are analyzed for two major winter U.S. east coast storms that exhibited considerable mesoscale features. Pronounced spatial and temporal continuity is noted for individual convective rainfalls within the cold air. Such features

can also be tracked in the wind and pressure fields. Finally, some thoughts are offered on the possible dynamic significance of organized mesoscale precipitation patterns, along with comments relevant to the forecasting of such patterns.

1. INTRODUCTION

Modern synoptic meteorology developed from the Norwegian school of thought on air masses and frontal structure shortly after the first world war. The novel schemes proposed at that time to explain the occurrence of precipitation in midlatitudes have withstood the test of time fairly well. Not all such precipitation could be explained by fronts, however. Recent research on a sub-synoptic scale (10–100 km) has indicated a need to modify the classical textbook structure of uniform, steady precipitation in advance of the surface warm front and brief, showery precipitation accompanying the surface cold front. Inspection of observed data disclosed that convective activity contributes significantly to precipitation totals within large-scale, midlatitude winter storms such as those typically found along the east coast of the United States in winter.

Tracton (1968) tried to quantitatively assess the contribution of convective activity to the total storm rainfall accompanying a major disturbance along the Atlantic coast on Nov. 29–30, 1963. He found that at least 30 percent of the total precipitation produced by the storm on an area average basis was attributable to cellular convection. These findings are significant in terms of the dynamical effects of latent heat release on overall storm evolution. Sanders and Olson (1967) stress this latter point, which is not without controversy (Schwarz 1968, Sanders and Olson 1968).

Kreitzberg and Brown (1970) looked into the three-dimensional structure of an occlusion through careful consideration of the mesometeorological (horizontal scales of 10–100 km) fields of wind, pressure, and precipitation. Browning and Harrold (1969, 1970), with the aid of sensitive Doppler radars, investigated in detail the vertical air circulation accompanying a frontal passage. Their results emphasized the importance of convective motions in terms of precipitation distribution within what otherwise might appear as a routine, steady type of rainfall pattern.

The above-cited research is important not only to the theoretical meteorologist, who wishes to learn more about the dynamics of the atmosphere, but also to the forecaster, the hydrologist, and the ecologist. To illustrate, let us assume that a moderately intense winter storm deposits the equivalent of 1–2 in. of melted precipitation over an area the size of New England in a 24-hr period. A careful inspection of the available data may disclose, however, that amounts in excess of 0.50 in. fell in less than an hour. If the ground is frozen or covered with snow, then a possible serious flood situation may arise. Clearly, the forecaster, as well as the hydrologist or forestry official, should be aware of the consequences of periods of intense rainfall within an apparent overall uniform precipitation situation.

The present paper is an outgrowth of an investigation of the small-scale variations of pressure, wind, temperature, and rainfall associated with gravity wave phenomena accompanying the passage of a winter east coast cyclonic disturbance. Additional details can be found in Bosart and Cussen (1973) and Bosart et al. (1972). We feel that the spatial and temporal continuity exhibited by some of these small-scale features should be pointed out to those researchers concerned with applications and forecasting.

2. SYNOPTIC SITUATION

Two east coast storms were selected for study on the basis of apparent widespread gravity wave activity. Both storms deposited copious precipitation from the gulf coast through eastern Canada. The first storm, from Dec. 3 to 5, 1968, was mostly rain while the second storm, from Mar. 3 to 5, 1971, was mostly rain in coastal locations and snow inland.

Data for this investigation consisted of National Weather Service surface and upper air teletype data, WBAN 10 surface records, WBAN 31 upper air records, and Environmental Data Service *Northern Hemisphere Data Tabulations, Hourly Precipitation Data, and Storm Data*.

Case of December 3-5, 1968

The surface and 500-mb synoptic situations are shown in figure 1. The 850-mb charts are provided (fig. 2A-2D) to delineate areas of warm and cold advection and to show the lower tropospheric moisture distribution. At 1200 GMT on December 3, a weak surface trough is evident over the Mississippi Valley with a ridge axis from James Bay, Canada, to Cape Hatteras, N.C. Precipitation is widespread along and north of the stationary front near the gulf coast. Previous 6-hr rainfall totals in excess of 2 in. were reported over parts of Louisiana and Mississippi. At 500 mb, there is a pronounced trough over the Central Great Plains. Cold advection into the trough suggests continuing intensification.

At 0000 GMT on December 4, the surface map is quite complex with Low centers over the Upper Michigan Peninsula and southeastern Kentucky and the suggestion of a center east of the Appalachian Mountains over North Carolina. Considerable gravity wave activity took place in the Georgia-Carolina region in the preceding 12 hr with peak amplitudes approaching 4 and 5 mb on time scales of 10-20 min. The largest 6-hr precipitation totals in excess of 1 in. are found along the southern Atlantic coast. The trough at 500 mb intensified, and continued cold advection into the trough suggests further intensification. In addition, the wavelength of the trough shortened, thereby favoring an increase in the upper tropospheric divergence in the southwest flow ahead of the trough axis. At 850 mb, nearly saturated conditions are evident over a much wider area at this time than 12 hr earlier.

By 1200 GMT on December 4, the surface system had deepened 12 mb as part of an elongated trough with separate centers on both sides of the Appalachian Mountains. The eastern center was still ill defined. A strong southeast geostrophic flow from the Atlantic points to heavy precipitation in New England. At 500 mb, the trough sharpened further while moving eastward at 25 kt. A strong south-southwest flow extends along the Atlantic coast.

At 0000 GMT on December 5, the surface low-pressure system has an unusual configuration; a trough extends from Montreal, Canada, to New York City, N.Y., and then northeastward to Cape Cod, Mass. Separate circulation centers exist in each of these regions with an overall deepening of 10 mb in the last 12 hr. Obviously, meso-scale effects are important here from a forecasting point of view. At 500 mb, the trough has begun to move northeastward in response to the next upstream short wave in association with a Low over western Lake Superior. Winds of 130 kt are reported in the southerly flow ahead of the trough.

Case of March 3-5, 1971

The synoptic situation associated with this case is shown in figure 3. At 0000 GMT on March 3, a wave disturbance is forming in southern Mississippi along a quasi-stationary front extending to the southern Atlantic coast.

The central pressure in the disturbance is 1004 mb. A well-defined baroclinic zone exists along the front and is especially pronounced at 850 mb (fig. 2E-2H). At 500 mb, a trough is located over the Southern Great Plains States. Strong cold advection into the trough again suggests intensification as in the previous case.

In the ensuing 12 hr, the surface wave deepens to 1000 mb while becoming better organized. The wave is located over extreme western Georgia, and an additional center is found over northeastern Tennessee. In the meantime, a major change takes place at 500 mb; height rises along the northern Atlantic coast coupled with height falls centered in the lower Mississippi Valley result in a much more amplified trough. Continued cold advection again favors additional intensification. Moisture has increased along the 850-mb baroclinic zone, but relatively unsaturated conditions exist southeast of the Low center.

By 0000 GMT on March 4, a disorganized low-pressure pattern is located over Virginia and North Carolina with three separate centers of around 994 mb. The circulation around the storm increased in the preceding 12 hr, and cold air is pouring southward to the rear of a sharp cold front crossing Florida. A more extensive saturation area is now evident in the warm air at 850 mb. The region of maximum cyclonic vorticity in the very strong 500-mb trough is becoming superimposed over the surface Low, and rapid deepening is forecast. Observed wind speeds of 140 kt at 500 mb over Georgia and South Carolina testify to the large vorticity values in the trough.

From 0000 through 1200 GMT on March 4, the storm deepened at the rate of 2 mb/hr reaching 970 mb just south of Long Island, N.Y., at that time. This rapid intensification is reflected in the exceptionally strong 500-mb trough. By 1800 GMT, the occluding storm had deepened to 961 mb, becoming one of the lowest central-pressure extratropical storms ever to cross eastern New England.

3. RESULTS

Case of December 3-5, 1968

Cumulative 6-hourly precipitation totals, based on the cooperative observers network in addition to National Weather Service and military stations, are shown in figure 4. Precipitation during the 12-hr period ending at 1200 GMT on Dec. 3, 1968, is associated with a small, flat wave that moved eastward along the quasi-stationary front at 25 kt (fig. 1). Most of the precipitation was convective in nature and took place along a surface convergence zone of northeasterly and southeasterly flow but definitely within the cold air. Nearly 3 in. of rain was measured at McComb, Miss., between 0600 and 1200 GMT.

During the following 6-hr, a surface trough extending southward from the Great Lakes began to interact with the gulf disturbance, resulting in the development of a separate Low center over central Tennessee by 1800 GMT. Precipitation was confined to the west of this center. The heaviest rainfall was associated with continued

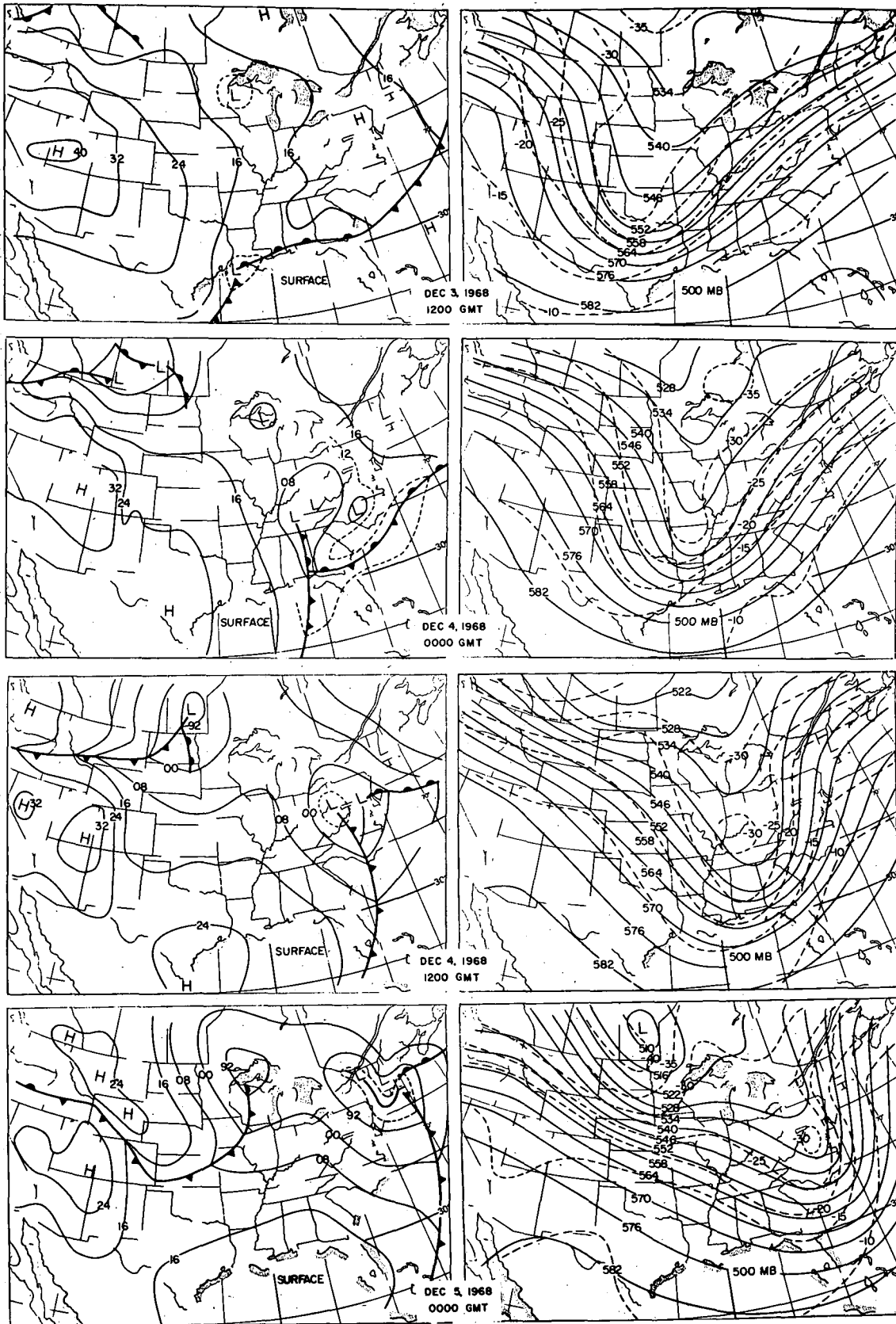


FIGURE 1.—Surface and 500-mb maps at times indicated for the December 1968 case. Isobars are drawn at 8-mb intervals (dashed 4 mb where necessary), 500-mb heights (solid) at 6-dekagram (dam) intervals, and 500-mb temperatures (dashed) at 5°C intervals.

convective activity as minor waves continued to ripple along the front. Especially heavy amounts (with hourly amounts in excess of 0.50 in.) were noted in the cold air

from Dothan, Ala., to Macon, Ga. Heavy rainfall was also observed in the warm air in the Tallahassee, Fla., area. Convergence along the Georgia and South Carolina

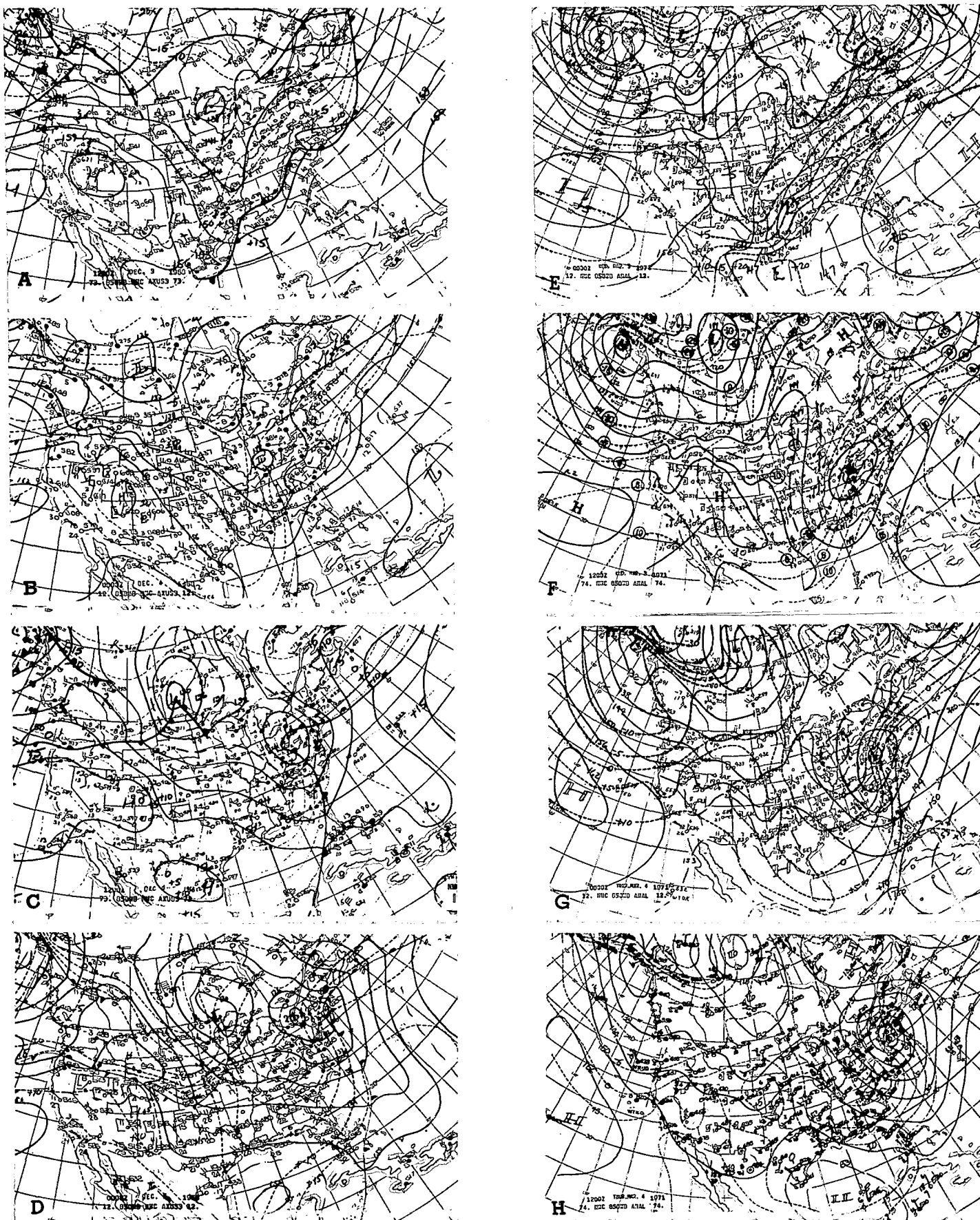


FIGURE 2.—The 850-mb charts for (A) 1200 GMT, Dec. 3, (B) 0000 GMT, Dec. 4, (C) 1200 GMT, Dec. 4, and (D) 0000 GMT, Dec. 5, 1972, and for (E) 0000 GMT, Mar. 3, (F) 1200 GMT, Mar. 3, (G) 0000 GMT, Mar. 4, and (H) 1200 GMT, Mar. 4, 1971. Heights are in dam (solid), isotherms are in $^{\circ}\text{C}$ (dashed), and winds are in kt. Filled-in station circles indicate temperature-dew-point spread $\leq 5^{\circ}\text{C}$.

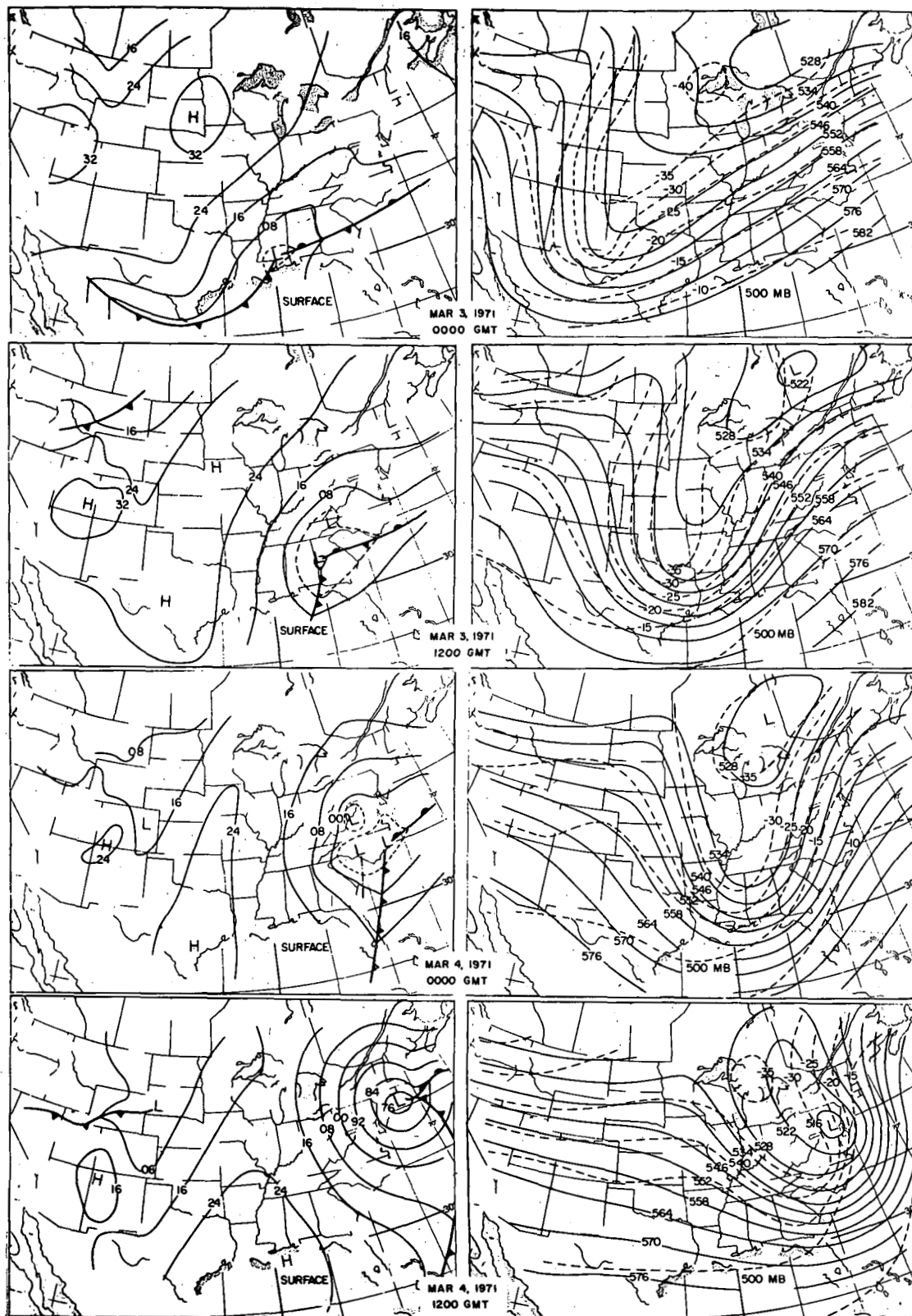


FIGURE 3.—Same as figure 1, for the March 1971 case.

coastline produced a northeastward extension of the heavy rainfall area. The relatively dry area over central South Carolina is supported by the narrow ridge of high pressure separating the trough regions (fig. 1).

By 0000 GMT on December 4, the precipitation areas had expanded on both sides of the Appalachian Mountains

in response to the evolving cyclonic disturbances. However, amounts were generally under 0.50 in. except in the Carolina convergence zone and the gulf coast region. The latter area was influenced by a squall line that developed ahead of the advancing cold front. During this time, a series of gravity waves moving east-southeastward over

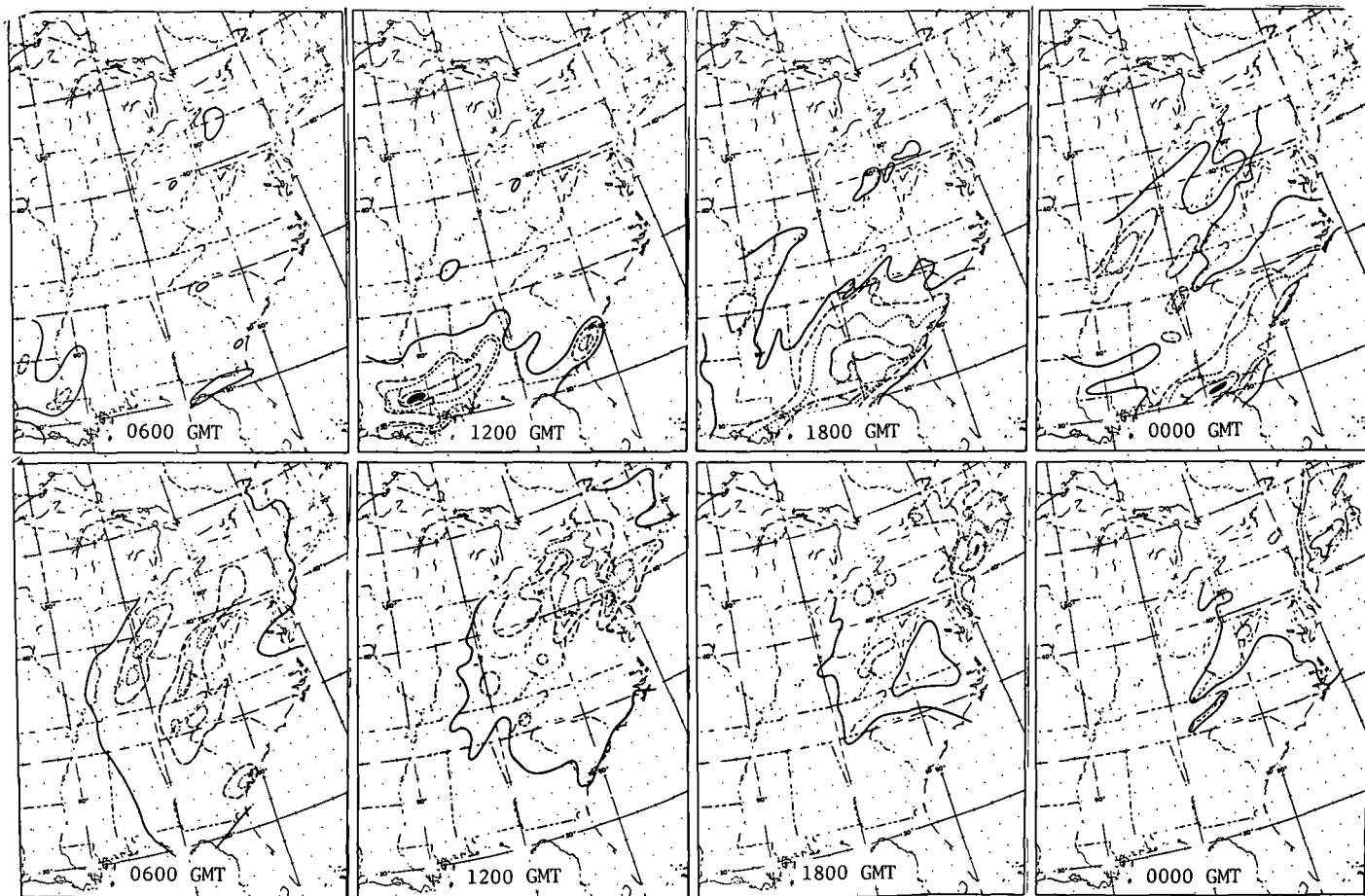


FIGURE 4.—Cumulative 6-hr precipitation for periods beginning 0000 GMT, Dec. 3 (upper left) through 0000 GMT, Dec. 5, 1968 (lower right). Contour intervals are 0.01 in. (solid), 0.25 in. (dashed), 0.50 in. (dotted), 1.00 in. (long-short dashes), and greater than 2.00 in. (solid, filled in).

the central Carolinas and Virginia were associated with rainfalls from 0.10 to 0.50 in. ranging from north to south. These waves had peak amplitudes of 2–4 mb and periods of roughly 1 hr. They formed west of the Appalachian Mountains and progressed to the Atlantic coast over a 12-hr period. Specific details can be found in Bosart and Cussen (1973).

The period from 0000 through 0600 GMT on December 4, witnessed the rapid northeast extension of precipitation in response to an increasing moist inflow from the Atlantic Ocean. Rainfall amounts from 0.25 to 0.50 in. were common in the Ohio and Tennessee Valleys as the circulation pattern strengthened west of the mountains. East of the mountains, conditions were becoming ripe for secondary storm formation as coastal winds veered to the south and southeast, thereby favoring development of a convergence region in the Chesapeake Bay area. Rainfall totals were generally less than 0.15 in. in the suspected secondary storm region. Scattered 0.25- and 0.50-in. rainfalls in the western Carolinas and Georgia were produced by the advancing cold front, while a small vestige of the coastal Carolina maximum remained.

From 0600 through 1200 GMT on December 4, the precipitation expanded northward and intensified, although the reported 6-hourly maximum amounts were less than 1 in. The main axis of heaviest precipitation

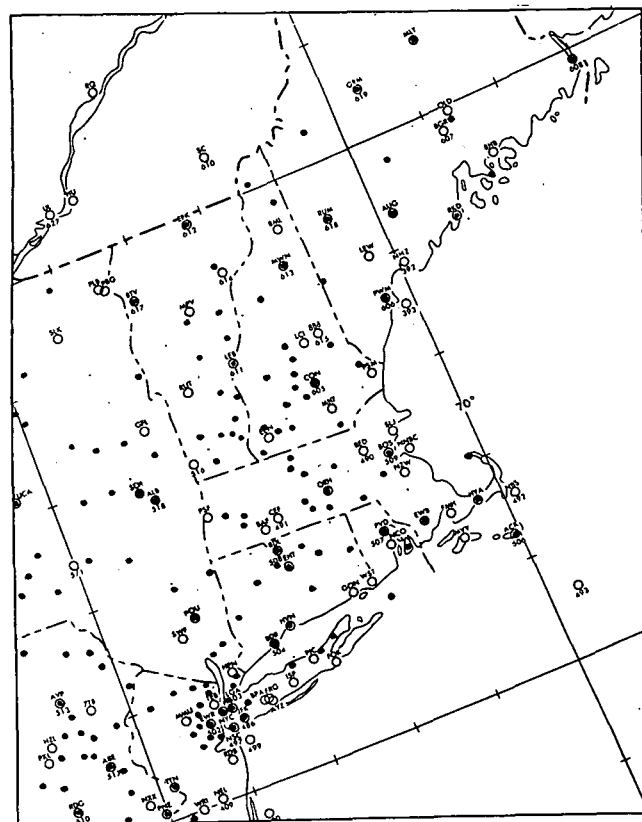


FIGURE 5.—Map of stations (solid circles) for which hourly precipitation data is available.

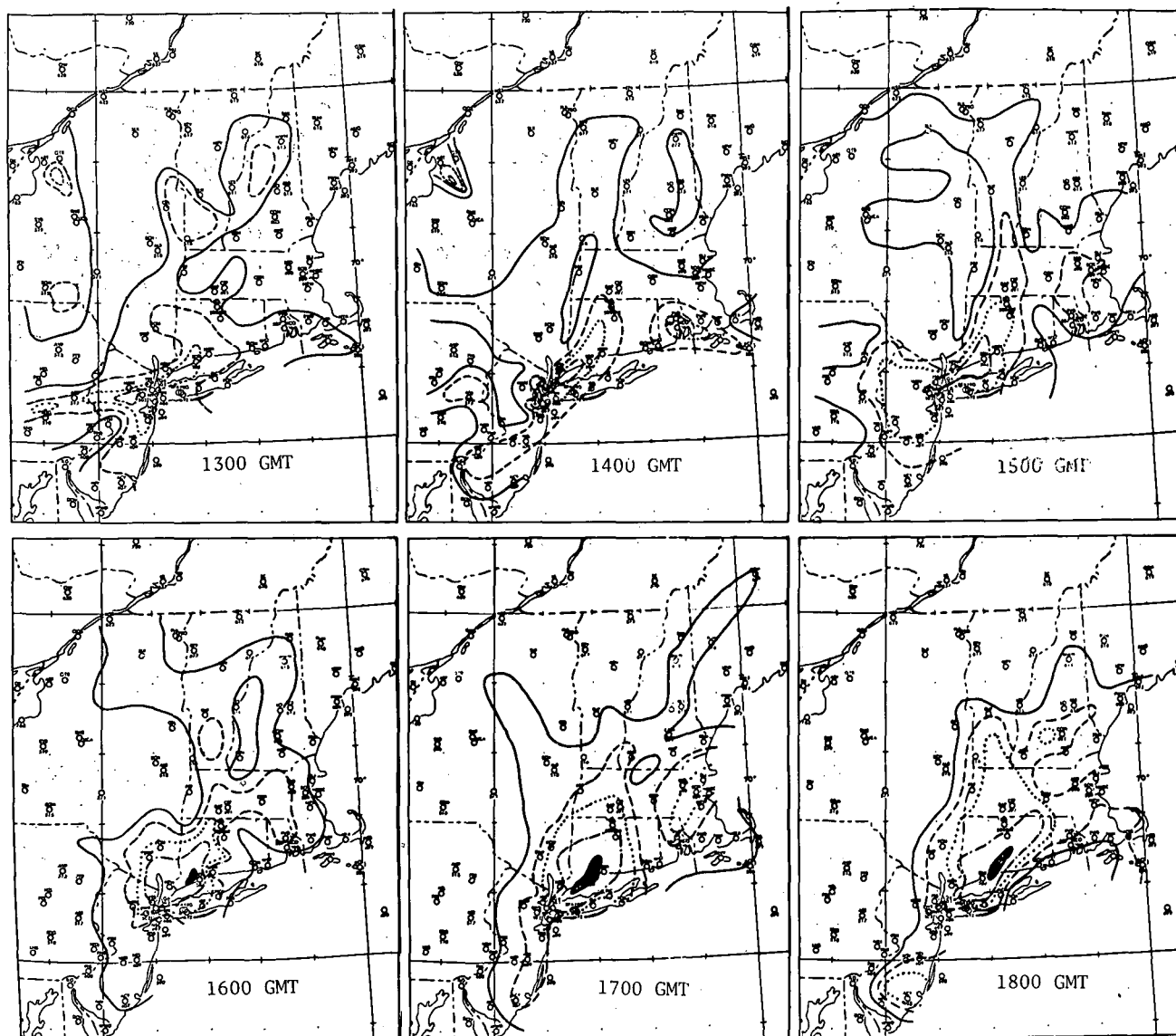


FIGURE 6.—Hourly precipitation maps from 1200 GMT (upper left) through 1800 GMT, Dec. 4, 1968 (lower right). Contour intervals are 0.05 in. (solid), 0.10 in. (dashed), 0.15 in. (dotted), 0.25 in. (long-short dashes), and greater than 0.50 in. (stippled).

extended north-northeast to south-southwest across central Pennsylvania and New York in response to favorable orographic factors ahead of the Ohio Valley Low. The rainfall tongue from central Virginia to the Washington, D. C., area in the previous 6-hr period became more pronounced by 1200 GMT. This tongue extended roughly from Washington to Allentown, Pa., to New York City. A detailed surface analysis indicated that a weak cyclonic circulation (akin to secondary storm formation) formed on the northern end of a squall line over Virginia around 0600 GMT. Enhanced low-level convergence north and east of the circulation center resulted in the rainfall maximum. The circulation center eventually dissipated near Scranton, Pa. Hourly precipitation amounts of 0.15–0.30 in. could be tracked northeastward with this feature. A mesoscale ridge was noted over extreme northeast Pennsylvania and the Catskill region of New York during this period with a corresponding reduction of rainfall. This behavior was very similar to that accompanying the central North Carolina ridge at 1800 GMT on December 3.

A decrease in precipitation intensity took place after 1200 GMT on December 4 in association with the western Pennsylvania Low. The most interesting feature of the 1200–1800 GMT period was the development of excessive rainfall in southern Connecticut. Bridgeport, Conn., recorded 2.22 in. in the 6-hr period. Most of this precipitation formed in conjunction with a convergence zone along the southern New England coast (Bosart et al. 1972). The detailed surface analysis disclosed that a small wave disturbance moved east-northeastward along this convergence zone with strong low-level moisture inflow from the Atlantic Ocean. Warm advection at 850 mb is pronounced, as can be seen from figure 2A–2D. Maximum rainfall occurred along and just north of this convergence zone in a manner analogous to a warm front.

Inspection of figure 1 discloses the rather complex surface pattern at 0000 GMT on December 5 with three separate cyclonic circulation centers over the New York–New England region. In addition to the analyzed cold and warm fronts, the coastal convergence zone, described

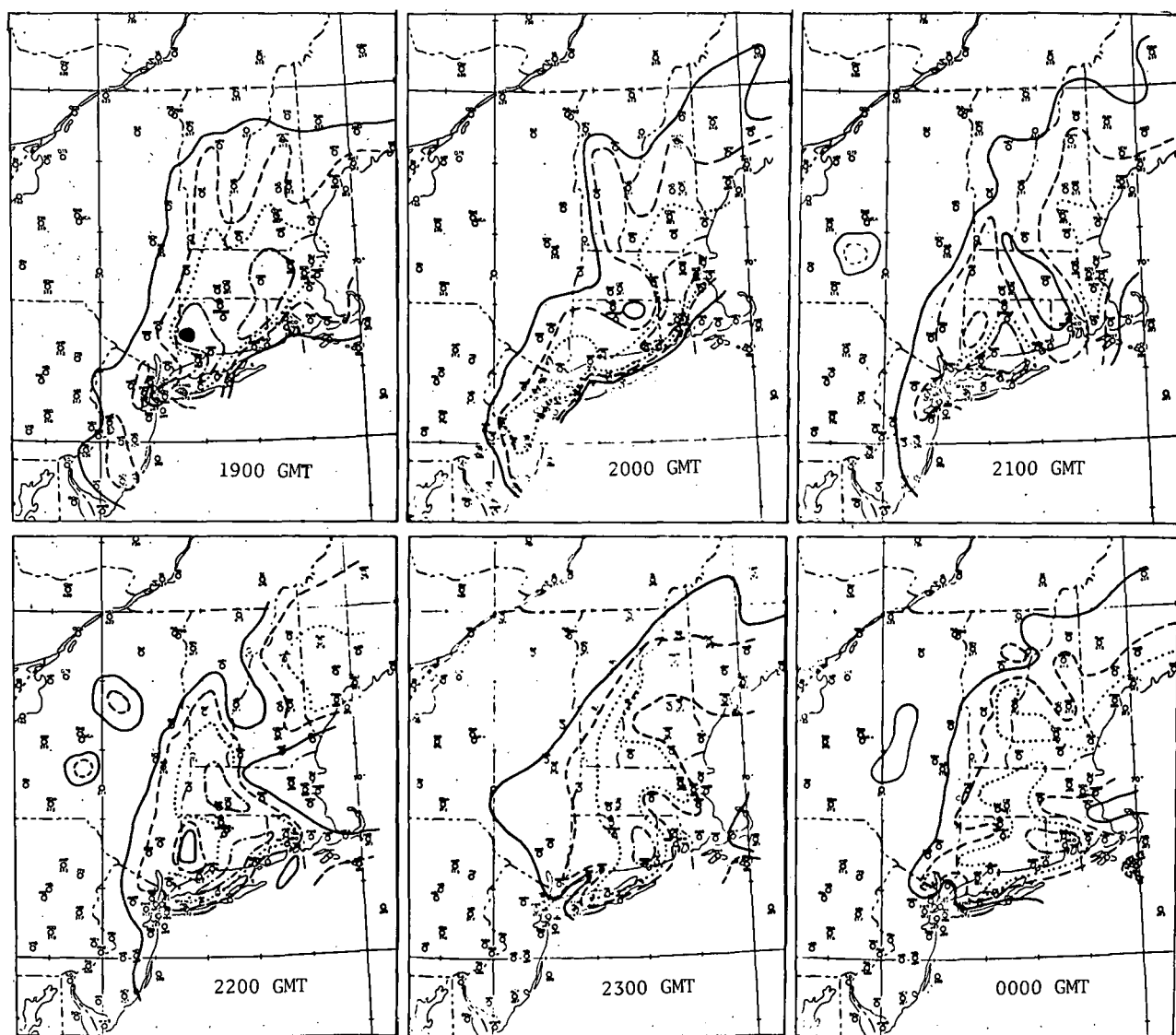


FIGURE 7.—Same as figure 6 for 1800 GMT, Dec. 4 (upper left) through 0000 GMT, Dec. 5, 1968 (lower right).

earlier, persisted and served as the track for the Low center located over southeastern Massachusetts at 0000 GMT. Heavy rainfall over Connecticut and Rhode Island, with much lighter amounts over Cape Cod, from 1800 to 0000 GMT reflects the passage of this wave center. An isolated, very heavy rainshower was observed during the warm front passage at Nantucket Island.

An extensive hourly precipitation analysis was made for the 48-hr storm period using data obtained from the *Hourly Precipitation Data* published by the National Climatic Center. In general, the analyses showed that mesoscale features discussed in connection with figure 4 could be followed on an hourly basis. A typical horizontal length scale was 100 km, while the motion was approximately with the mean 700-mb wind. Obviously, nothing can be said about the structure and motion of individual convective elements on such scales. For purposes of this paper, the focus is on the 18-hr period from 1200 GMT on December 4 through 0600 GMT on December 5 in the New England, New York, New Jersey, and Pennsylvania

region. As can be seen from figure 1, the surface pattern was confused during this period. Figure 5 shows the distribution of reporting cooperative precipitation stations, while figures 6 and 7 reveal the hourly precipitation patterns.

Rapid development of heavy rainfall along the southwestern Connecticut coast after 1200 GMT culminated in a total of 0.75 in. at Bridgeport for the hour ending at 1700 GMT (fig. 6). Figure 8 shows the triple recorder precipitation record for the nearby station of New Haven, Conn., during the period of heavy rainfall. Within the heavier precipitation period of just over 2-hr duration are several 10-min periods of rainfall rates approaching 25 mm/hr, which are indicative of the small-scale convective activity within the storm system. During this period, the surface winds became convergent along the coast with the maximum convergence occurring 1–2 hr prior to the heaviest rain. Similarly, the region of active precipitation over coastal regions was relatively stationary around 1200 GMT despite 40- to 50-kt winds between 700

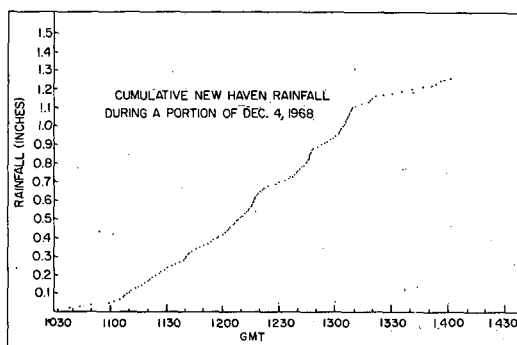


FIGURE 8.—Cumulative rainfall (in.) at New Haven, Conn., from 1030 to 1430 GMT, Dec. 4, 1968.

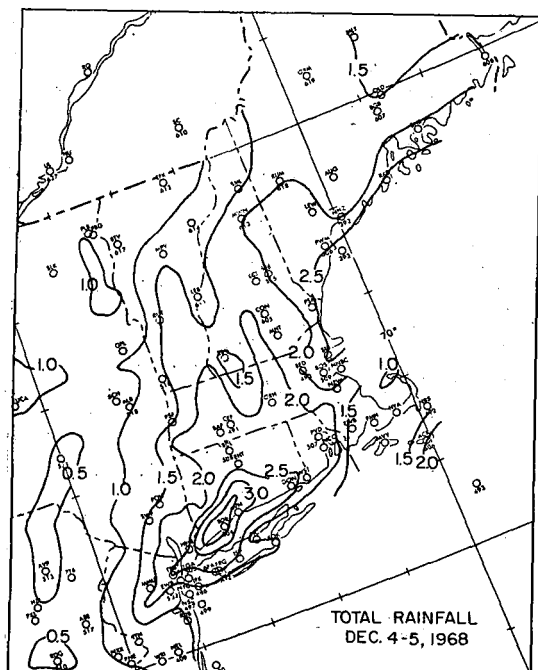


FIGURE 9.—Total storm precipitation (in.) for Dec. 4-5, 1968.

and 800 mb. Evidently, local convergence was serving to generate new precipitation cells, while individual cells moved northeastward.

The WSR-57, 10-cm radar report from New York City indicated essentially zero system movement from 1145 through 1345 GMT on December 4, although individual cells were moving from 220° at 45-50 kt. Maximum reported cloudtops were in the vicinity of 20,000 ft. By 1800 GMT, the precipitation system was moving from 270° and 280° at 20-25 kt, while individual cells moved as before. Again, maximum cloudtops were reported near 20,000 ft. No special mention was made of any thunderstorm or other convective activity in the vicinity of Bridgeport, although that station was well within the operational range of the WSR-57 radar at New York City.

Between 1800 and 2100 GMT, well-defined spatial and temporal continuity was exhibited by the maximum rainfall region as it moved from Bridgeport toward Boston, Mass. This path closely corresponded with the coastal

region of maximum convergence mentioned earlier. Enhanced rainfall just north of the convergence zone is consistent with the quasi-geostrophic omega equation whereby the greater low-level veering of the wind and hence warm advection would favor stronger ascent.

From 2000 GMT on December 4 to 0100 GMT on December 5, it was possible to follow another region of maximum rainfall from New York City to Boston. This activity was associated with the coastal wave that eventually became the main secondary low-pressure area and also followed the maximum convergence zone. Rainfall was generally light over Cape Cod and the nearby islands with the exception of Nantucket where 0.85 in. fell in a heavy convective shower preceding the warm front passage. The final well-defined rainfall area was associated with the surface trough to the west of the Hudson Valley at 0000 GMT on December 5. A path can be traced across southeastern New York to northeastern Massachusetts from 0200 through 0600 GMT. Figure 9 shows the total storm precipitation in this same region. Note the axis of higher rainfall extending from southwestern Connecticut toward Boston.

Case of March 3-5, 1971

Six-hourly precipitation maps for March 3-4, 1971, are presented in figure 10. The situation is similar to the previous case except that snow over the central and northern Appalachian Mountains lends the usual complications in determining liquid water. In the 12-hr period ending at 0600 GMT on Mar. 3, 1971, the precipitation shield expanded northeastward and northward as a low-pressure wave moved along the quasi-stationary front into central Alabama. The eastern axis of maximum precipitation was associated with frontal convergence, while the western axis lies along and just to the north of the track of the wave center. Maximum hourly rainfall totals were generally around 0.50 in. with an isolated accumulation of nearly 2 in./hr in southeast Mississippi. Convective rainfall is significant within the cold air in a manner analogous to the December 1968 case. In the following 6 hr, the precipitation intensified northeastward with a band of nearly 2 in. from western Georgia to central North Carolina. Some hourly amounts were in excess of 1 in. in association with convective activity in a strongly convergent region just ahead of the surface wave. At the same time, a separate Low center embedded in the 850-mb baroclinic zone over northeast Tennessee was helping to extend precipitation up to southern New York.

From 1200 to 1800 GMT, local convective rains of up to 4 in. were reported from south-central Georgia toward the North Carolina border. Maximum hourly rains ranged from 1 to 2 in. Most of this activity was associated with a series of heavy thunderstorms and showers moving northeastward on both sides of the stationary front in advance of the wave disturbance, which showed little deepening beyond the diurnal tendency. The situation was considered dangerous enough, however, to warrant a tornado watch over portions of North Carolina and Virginia. The surface pattern remained confused, with

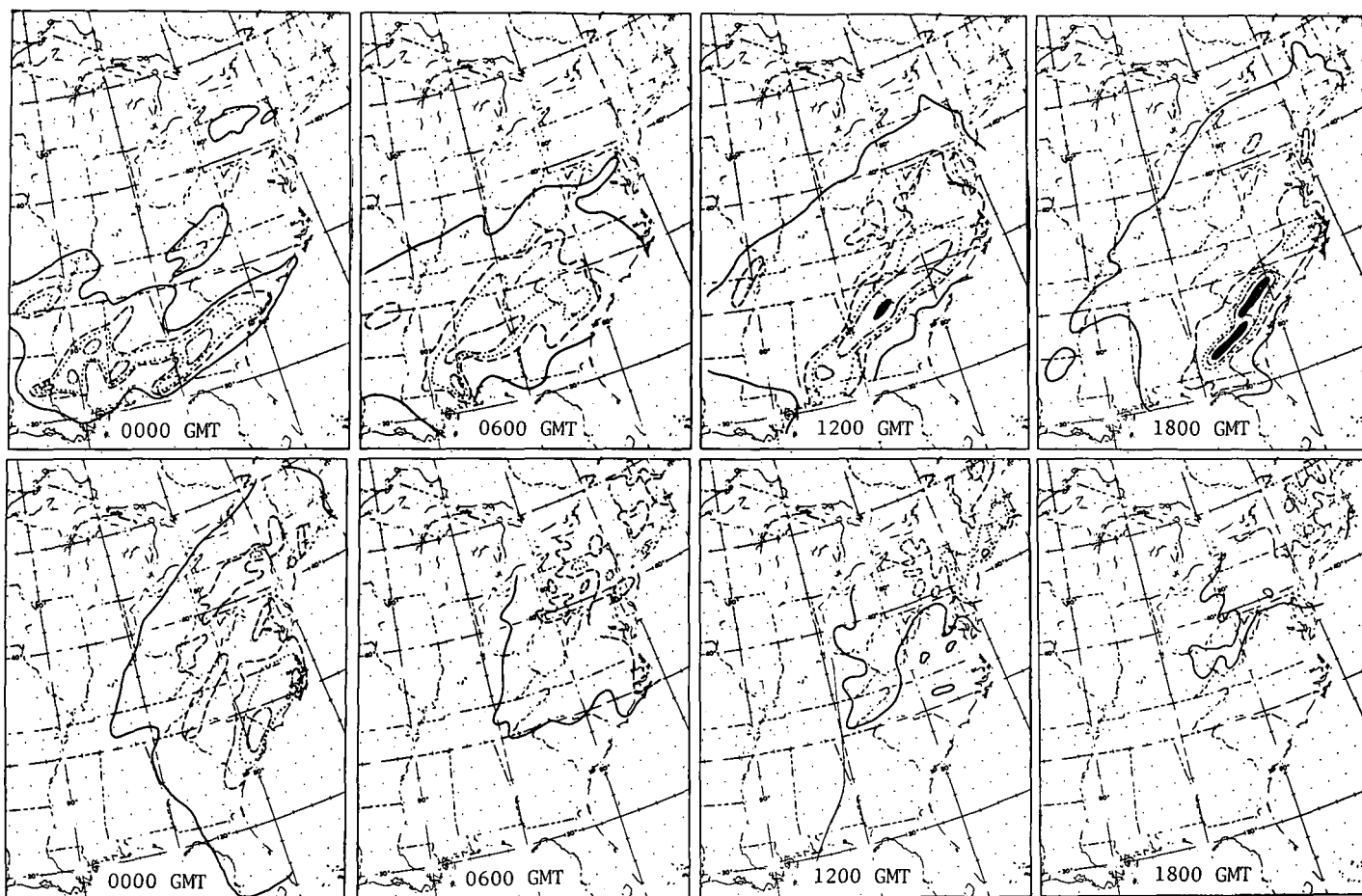


FIGURE 10.—Cumulative 6-hr precipitation for periods beginning 1800 GMT, Mar. 2 (upper left) through 1800 GMT, Mar. 4, 1971 (lower right). Contour intervals are 0.01 in. (solid), 0.25 in. (dashed), 0.50 in. (dotted), 1.00 in. (long-short dashes), and greater than 2.00 in. (solid, filled in).

three separate cyclonic circulation centers visible. Gravity wave activity in the cold air over the Carolinas and Virginias was noted, apparently in response to the convective activity farther to the south. By 0000 GMT on March 4, this strong convective activity reached the Carolina coast and diminished in intensity as a cold front and secondary trough passed through the region.

Rapid surface deepening at the rate of 2 mb/hr took place over the next 12 hr from 0000 to 1200 GMT on March 4 as the surface Lows consolidated into one system and became better organized under the influence of a strong increase in cyclonic vorticity advection with height. Convective precipitation over land all but disappeared by 0600 GMT with all observed 6-hr amounts under 0.50 in. Coastal radar reports documented the decrease of the Carolina convective activity as the system moved out over the Atlantic. In general, most cloudtops in range of coastal radar remained below 25,000 ft. as the storm began to intensify rapidly. Up to 1 in. of precipitation fell during the next 6 hr as the Low intensified rapidly. Note that the axis of heaviest precipitation extended from just east of New York City toward extreme southwestern Maine from 0600 to 1200 GMT. This was similar to the December 1968 case described earlier with a convergence region centered just inland from the coast. Within this region, individual precipitation

cells exhibited spatial and temporal continuity although not to the extent of the previous case. Outer Cape Cod and Nantucket Island, to the southeast of the coastal convergence zone but still north of the surface warm front, reported reduced rainfall totals. The storm achieved peak intensity by 1800 GMT and then began to fill slowly. Heaviest precipitation was confined to the area of strong moist inflow from the Atlantic northeast of the Low center. Precipitation tapered off in the form of cold air instability showers to the southwest of the Low center.

4. DISCUSSION

A number of results from this paper are important from both the forecast and the research points of view. Obviously, in any such study, the question of representativeness of two cases should be raised. While individual details may vary, it seems fair to state that a large fraction of coastal storms will exhibit behavior similar to these two cases. Equivalent melted precipitation will range from 1 to 2 in. within 12–24 hr over a 5×10^5 km² area.

What is especially interesting here is that the bulk of such rainfalls may occur on time scales of several hours. One- to 2-in. convective rains in less than 1 hr during a winter storm compare favorably with some of the more intense summer thundershowers. Clearly, this information

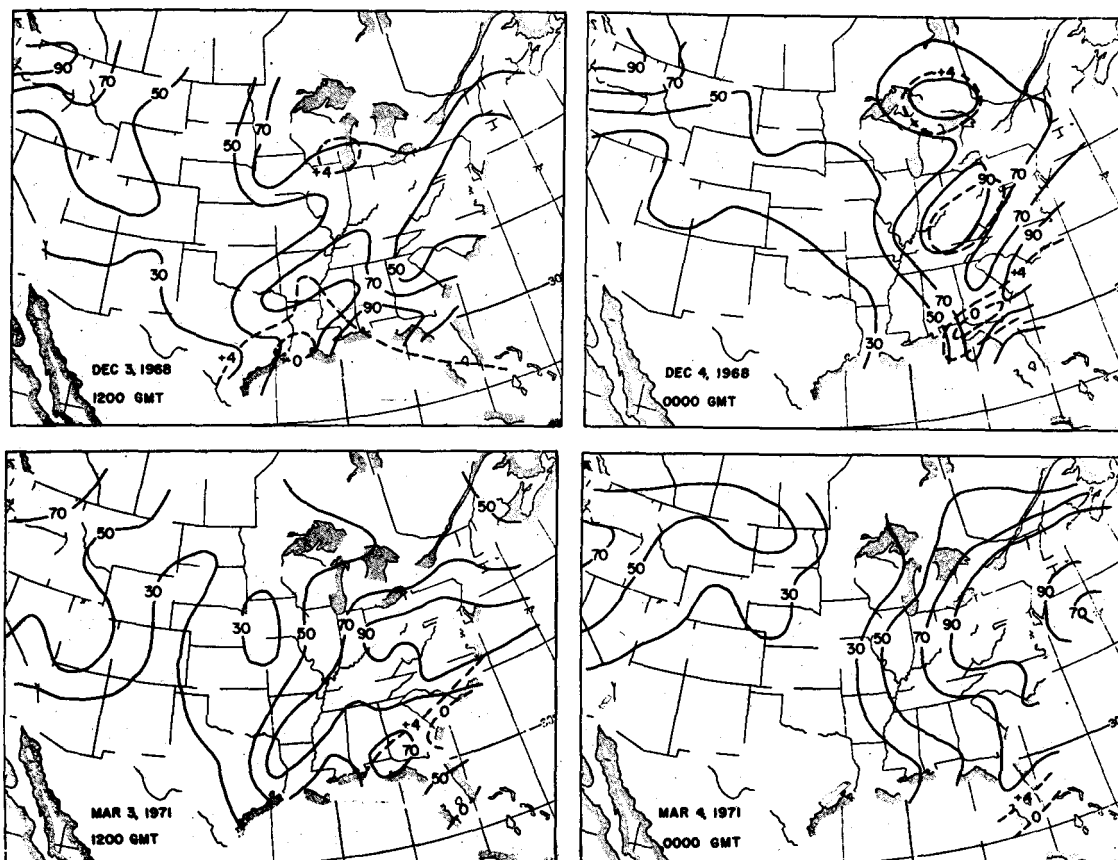


FIGURE 11.—Mean surface to 500-mb relative humidity (solid) and lifted index (dashed) for values less than +4 at times indicated.

is useful in flash flood forecasting. In the March 1971 storm, flash flood warnings were raised over portions of the Carolinas within 6 hr of the onset of heavy rains. This, in turn, raises the question of the predictability of such mesoscale events. Usually, such details in the meteorological fields are not detectable on the routine surface analyses transmitted every 3 hr over national facsimile. In addition, it will be some time before numerical prediction models can handle such forecasts. The current limited-area fine mesh (LFM) numerical prediction model, while a step in the right direction, is not capable of handling such details, especially convective precipitation.

The results of these detailed precipitation analyses bring up some questions about the role of latent heat in cyclogenesis. Danard (1964) showed the importance of latent heat release and a variable static stability in the computation of diagnostic, quasi-geostrophic omegas for a winter mid-latitude cyclonic disturbance. However, his results must be treated with caution because of the large grid spacing involved and the variance from strict, quasi-geostrophic theory. Krishnamurti and Moxim (1971) included convective and nonconvective latent heat release in their model computations of vertical motions in an attempt to improve squall line and cold-front convective rainfall prediction. Their comparisons of forecast precipitation based on instantaneous omegas with observed precipitation gave encouraging results. A key idea in that paper was the argument against the removal of synoptic scale conditional instability in extratropical disturbances by the moist convective adjustment process in numerical prediction models.

Figure 11 presents the mean relative humidity and stability maps for the development periods of the two storms under discussion in this paper in an effort to look at the role of latent heat on storm evolution. Considerable reanalysis of the maps was necessary because of the receipt of delayed data not available on a real-time basis. The December case shows the northeastward expansion of two moist tongues with a relatively dry area in between. The southern moist tongue is associated with disturbances along the stationary front noted earlier, while the northern moist tongue is associated with the Appalachian Low center. Conditional instability is a characteristic of both the relatively dry area and the moist region to the south. Convective activity was also noted in the relatively dry region across Louisiana toward South Carolina. Athens, Ga., reported a relatively dry and stable lower troposphere at 0000 GMT on December 4, which is consistent with surface reports whereby convective rainfall ceased after the passage of several gravity waves. It should be noted, however, that this sounding was conditionally unstable from 750 to 500 mb.

The March case is characterized by a rapid expansion of the high mean relative humidity area to include the vicinity of the storm center by 0000 GMT on March 4. Greatest instability as computed by the lifted index is confined to extreme coastal regions and within the warm sector.

A somewhat different picture is portrayed in figure 12, which shows equivalent potential temperature profiles versus pressure for a number of stations for both cases. Conditionally unstable regions are characterized by an

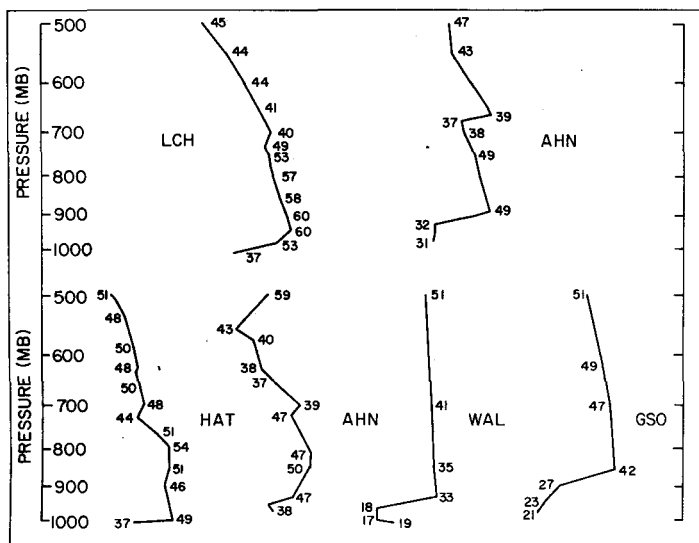


FIGURE 12.—Profiles of equivalent potential temperature and temperature on a skew T -log p background. Top row: Lake Charles (LCH), La., at 1200 GMT, Dec. 3, 1968, and Athens (ATH), Ga., at 0000 GMT, Dec. 4, 1968. Bottom row: Cape Hatteras (HAT), N.C., Athens, Wallops Island (WAL), Va., and Greensboro (GSO), N.C., at 1200 GMT, Mar. 3, 1971.

upward decrease of equivalent potential temperature. Lake Charles (LCH), La., and Athens (AHN), Ga., for the December case and Hatteras (HAT), N.C., and Athens for the March case are examples of relatively deep conditional instability within the cold air. Recall that severe convective activity broke out after 1200 GMT on March 3 along the Athens-Cape Hatteras line. Greensboro (GSO), N.C., and Wallops Island (WAL), Va., exhibit the more traditional overrunning cold air situations.

These results suggest that convective activity along quasi-stationary fronts associated with weak disturbances serves to bring the synoptic scale to saturation, at least in the lower half of the troposphere. If large-scale divergence aloft, in conjunction with strong upward cyclonic vorticity advection, becomes superimposed over such a region, then explosive cyclogenesis is likely to result. At the outset, when conditional instability is general along a quasi-stationary baroclinic zone, surface convergence, coupled with only a weakly favorable divergence field aloft, appears sufficient to trigger an outbreak of convection. Figure 13 is an hourly plot of lowest surface pressure versus time of the March storm gleaned from hourly teletype reports. It is uncorrected for the semidiurnal variation, but the overall pattern clearly shows a pronounced surface deepening beginning around 0000 GMT on March 4. This deepening is in conjunction with the favorable patterns aloft, but extensive convective activity within the previous 6–12 hr brought the synoptic scale environment to saturation in the vicinity of the storm.

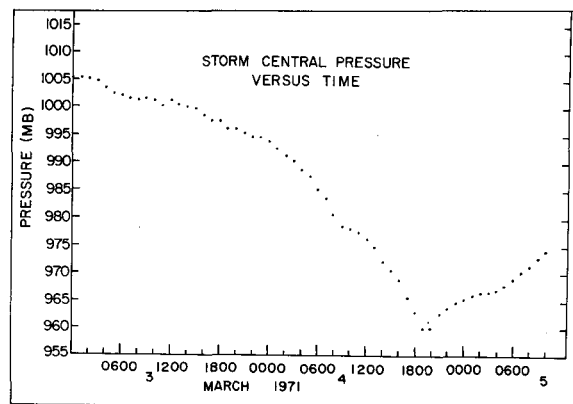


FIGURE 13.—Hourly central pressures (mb) for the storm of Mar. 3–5, 1971. Times are all GMT. Values are derived from hourly maps and are uncorrected for the semidiurnal pressure oscillation.

ACKNOWLEDGMENTS

Research presented in this paper was made possible through Grant 020-7151A from the Research Foundation of the State University of New York. The author extends his appreciation to John P. Cussen, Jr., for analysis work, Andrew Fritz for data plotting, Marilyn Peacock for drafting the figures, and Patricia Rinaldi for typing the manuscript.

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[Received May 22, 1972; revised August 23, 1972]